

Contained Detonation System for Destroying UXO Containing Chemical Agents

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ABSTRACT

In January 2000, the Department of Defense Explosive Safety Board (DDESB) certified DeMil International's Model T-10 transportable Donovan Contained Detonation Chamber technology suitable for destroying UXO containing conventional explosives. The T-10 system is comprised of a detonation chamber, an expansion chamber and an air pollution control device appropriate for the type of material being destroyed. Because remediation and range clearance activities sometimes uncover UXO containing chemical warfare materiel (CWM), the US Army Engineering and Support Center, Huntsville (USAESCH) conducted a proof-of-concept study evaluating the feasibility of developing a safe, easy-to-operate, transportable technology for destroying CWM UXO. This feasibility study involved combining a transportable contained detonation chamber from DeMil International, Huntsville, AL with a USAESCH Vapor Containment Structure (VCS) already certified by the DDESB as suitable for controlling the emissions from detonated CWM. In this study, sheet explosive was used to destroy canisters containing methyl salicylate (a mustard simulant) in a DeMil International Model T-3 detonation chamber and then surface wipe and air samples were collected to determine the quantity of methyl salicylate remaining after the detonation. This paper provides an overview of the emissions tests and an interpretation of the test results. In each of the four detonations conducted, at least 99.9% of the simulant was destroyed by the detonation itself. The tests also showed that

when the T-3 was inside the VCS, MS did not enter the environment.

INTRODUCTION

This paper describes the results from a study which evaluated the feasibility of safely and efficiently destroying UXO items containing chemical agent materials by detonating them in a chamber housed in a vapor containment structure owned by the US Army Engineering and Support Center, Huntsville (USAESCH). The study was conducted by ZAPATA ENGINEERING, P.A. (ZAPATA) for the USAESCH under Contract No. DACA87-95-D-0026.

The work was carried out by a team comprised of staff from USAESCH, ZAPATA, and two ZAPATA subcontractors, Southwest Research Institute, Inc. (SwRI) and Sudhakar Company, Inc. (Sudhakar). As the funding organization, USAESCH was responsible for procuring the contractor services, monitoring the contractor's efforts, controlling the budget and schedule, reviewing project work plans, and coordinating document reviews. ZAPATA, as the prime contractor, was responsible for providing all engineering support and services for the tests including management of subcontractor personnel and control of the project schedule and budget. SwRI and Sudhakar conducted the detonation tests, collecting air and surface wipe samples and analysis of waste residue generated during the testing.

EXPERIMENTAL

Vapor Containment Structure (VCS)

The VCS is a corrugated steel Quonset-type structure located at SwRI's Ballistics and Explosives Range in San Antonio, Texas. It is approximately 12.2 m long by 9.1 m wide by 4.9 m high and has an interior volume of approximately 375 m³. It is equipped with an air filtration system certified for removing chemical agent materials and their detonation by-products from air streams.

T-3 Model Detonation Chamber

A DeMil International Inc. transportable Model T-3 Contained Detonation Chamber (CDC) was used as the blast containment chamber. The expansion chamber, the pea gravel and air pollution control unit (APCU), all standard equipment with DeMil International CDC systems, were not used for these tests. (The pea gravel both attenuates the blast pressure and aids the APCU in removing detonation products from the exhaust gases.) They were not used, because the USAESCH wanted to evaluate the ability of the detonation itself to destroy the CWM simulant. The T-3 was transported on a flatbed trailer by Sudhakar to SwRI's ballistics and explosives range in San Antonio, Texas for the tests. The T-3 is approximately 1.2 m high by 0.95 m wide by 1.5 m deep. Including its vent tubes and exhaust manifolds it has a total volume of 0.9 m³ and its total interior surface area is 65,000 cm².

CWM Simulant Items

Methyl salicylate (MS) was the CWM simulant used in the four detonation tests which comprised the feasibility study. MS, which is also called oil of wintergreen, is an industrial chemical which serves as a simulant for the chemical agent, mustard. It is composed of 100 percent volatiles, produces relatively non-toxic breakdown components, and has a vapor pressure of 1.4 mm of Hg at 20 °C. For the detonation trials, the MS was placed in thin-walled, glass-lined metal containers to simulate a UXO containing CWM. The MS was added to each container by pouring a predetermined volume into the container and then sealing the container with the screw-

top closure. No explosives were placed inside the container. Four CWM munitions were assembled at the test site, one for each test.

Explosives Configuration

Detasheet, a commercially available, sheet explosive which has a rubber like appearance, was used as the donor charge material. It is composed of acetyl tributyl citrate, nitrocellulose and pentaerythritol tetranitrate. A 4:1 explosive-to-simulant ratio was used in each test in an effort to completely destroy the simulant, while adhering to the T-3's operating specifications. For each test the specified weight of donor material was wrapped around the container containing the CWM simulant. Exploding bridge wires (EBW) were used as detonators, since they are inherently less susceptible to accidental detonation during handling and setup than devices containing primary explosives. After each test detonation, a decontamination mixture was detonated inside the blast chamber. Each of the four decontamination detonations utilized a combination of 223 g of baking soda, 567 g of water and 454 g of Detasheet.

Air and Interior Surface Sampling and Analysis for Simulant

Air samples were collected using DAAMS tubes and surface wipe samples were collected using gauze pads. Air sampling was initiated just before the detonation and continued for 40 to 80 minutes after the detonation.

Surface wipe sample was collected by wiping a 235 cm^2 area of the interior of the T-3 after the detonation. Two wipe samples were collected after each detonation. (Because the concentration of MS in the air can be as high as 11.8 g/m^3 at 20°C , we were not expecting to find meaningful amounts of MS on the interior surfaces of the T-10, but we took wipe samples just in case the unexpected happened.)

Detonation Tests

In two of the four tests, plastic bags containing water were suspended from hooks on the ceiling of the T-3. Water was not used in the other two detonation tests. The purpose of using water in some tests, but not in all tests was to provide a qualitative assessment on the potential to use high temperature steam (produced by the high temperature of the detonation) to hydrolyze any simulant which was not destroyed in the detonation itself. (NOTE: DeMil International's CDC systems use water to attenuate the temperature and blast energy released by the detonation.) Table 1 presents the test conditions used in each of the four detonation tests which comprised the feasibility study. A more detailed description of each tests is presented below.

Tests 1 and 2. The first two detonation tests were conducted with the T-3 located outside the VCS. The detonation products exiting from the T-3 exhaust manifold entered a flexible, 6.1 m long, 1.2 m diameter tube attached in a leak-free manner to the T-3 exhaust manifold. The total interior volume of the tubing was 7.5 m^3 and its interior surface area was $23,180 \text{ cm}^2$. In Test 1, the DAAMS tubes were located in the flexible tube at distances of 0.9, 1.8, and 2.7 m from the T-3 exhaust manifold exit. The sampling locations were selected to obtain information of the amount of MS escaping the T-3. Because the DAAMS tube located at 0.9 m was destroyed during the detonation, the locations of the DAAMS tubes for Test 2 were changed to 1.8, 2.7 and 3.7 m from the T-3 manifold exit. Test 1 used 113 g of MS, four plastic bags, each

containing 113 g of water and 454 g of Detasheet and Test 2 used 42 g of MS and 170. g of Detasheet. No water was used in Test 2..

Tests 3 and 4. These tests were conducted with the T-3 on a trailer inside the VCS. The gases leaving the T-3 exhaust manifold vented directly into the VCS. For these tests, the doors of the VCS were closed, and the louvered air exchange vent was partially closed to ensure that any CWM simulant discharged from the CDC would exit from the VCS only through the air filtration system. In these tests, one DAAMS tube was mounted on the east-facing side of the trailer and another was mounted on the west-facing side. In addition, to determine whether any CWM simulant released into the VCS was able to pass through the air filtration system, two other DAAMS tubes were located at the exit from the discharge stack of the air filtration system. Test 3 used 113 g of MS, four plastic bags (each containing 113 g of water) and 454 g of Detasheet and Test 4 used 113 g of MS and 454 g of Detasheet. No water was used in Test 4.

Calculation of Final Volume of the Detonation Plume

Tests 1 and 2. For these tests where the T-3 vented into the 7.5 m^3 (1.3 m diameter, 6.3 m long) circular tube, the final plume volume was assumed to be 8.4 m^3 , which is the total volume of the T-3 and the tube. That is, it was assumed that, while the air samples were collected, all of the detonation plume remained distributed between the T-3 and the tube. We believe that this is a reasonable assumption for the following reasons. First, the initial volume of the plume (corrected to STP conditions) for each detonation was always less than 1.2 m^3 . Second, because of the design features of the T-3 and the differences in density and temperature between the plume and the ambient air in the tube, the plume entering the tube from the CDC had the characteristics of plug flow, i.e., it simply pushed the ambient air in the tube out without mixing with it and did not exit the tube. Third, the air sampling was completed very soon after the detonation.

Tests 3 and 4. For these tests where the CDC vented directly into the VCS and a fan was used to purge the 0.9 m^3 CDC, the final plume volume was assumed to be the same as the volume of the building (375 m^3).

Calculation of Total Mass of MS on All Interior Surfaces.

The area of the interior surfaces covered by the two surface wipes was 470 cm^2 , which is approximately 0.7% of the total interior surface of the T-3 ($65,000 \text{ cm}^2$). It's customary in assessing the destruction and dispersion of chemical agents to sample between 0.3 and 2% of the surfaces exposed to the agent and to assume that the average concentration measured by the wipe samples is representative of the average concentration for all agent-exposed surfaces. This was the approach used to calculate the total mass of MS on the interior surfaces of the T-3.

RESULTS AND DISCUSSION

Table 2 contains the concentrations of MS found from each surface wipe and from each the DAAMS tubes, with the exception of the four DAAMS tubes which collected samples from the air filtration unit exhaust. The results from these latter DAAMS tubes are not presented because they did not detect any MS in the air filtration unit exhaust.

To provide a point of reference, if none of the 113 g of MS used in Tests 3 and 4 had been destroyed, the concentration of MS in the VCS would have been 31,300 ug/m³. This concentration is less than 0.25% of the maximum concentration (11,800,000 ug/m³) that could present if the air was saturated with MS. (As noted in the Experimental section, because of the high vapor pressure of MS, we expected to find only a minuscule amount of MS on the interior surfaces of the CDC. The results in Table 2 confirm the validity of this hypothesis.)

Table 3 contains the total micrograms of MS found in the detonation plume and on the interior surfaces of the T-3 for each test. These totals for the plumes were calculated by multiplying the average concentration for the DAAMS tubes by the appropriate final plume volume (8.4 m³ for Tests 1 and 2; 375 m³ for Test 3 and 4) and the totals for the interior surfaces were calculated by multiplying the average concentration for the wipe samples by the total interior surface area of the T-3.

Table 4 presents the total mass of MS remaining after each detonation and an estimate of the percentage of the initial mass of MS destroyed in the detonation. The total mass values in Table 4 are simply the sum of the total masses of MS in the plume and on the surfaces contained in Table 3. The estimated percentage of MS destroyed were calculated by subtracting the total MS remaining value from the initial mass of MS and dividing the difference by the initial mass and converting the decimal value which resulted to a percentage value.

These percentages show that in every test, at least 99.9% of the MS was destroyed. These high percentages are particularly impressive because when you consider the following. First, the masses of sheet explosive and water and their placement relative to the simulant were not optimized to ensure complete destruction of the MS. Second, the similarity between the % destruction values for the wet and dry detonations indicates that the high temperature hydrolysis reaction, that was expected for Test 1 and 3, apparently did not occur. Why not? One of the most likely reasons is that the quantities of water and explosive used were much too large for the volume of the T-3 and the mass of MS.

Based on the results of these tests, the USAESCH has contracted with DeMil International to begin a study to develop a fully-contained, transportable system for use in destroying UXO containing CWM. This system will be developed by combining a complete DeMil International CDC system with the USAESCH's VCS and then conducting the testing needed to optimize the detonation conditions so as to maximize the destruction of the chemical agent in the detonation chamber.

In conclusion, it should be possible to develop a transportable CDC system can be developed which will be capable of destroying CWM UXO, even those containing arsenic compounds. This conclusion is based on the emissions testing reported here, the emissions testing results obtained in January 2001 from the DeMil International Model T-10 operating at the Massachusetts Military Reservation¹ and emissions testing and modeling results reported elsewhere.^{2, 3, 4, 5, 6}

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Disclaimer

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Table 1. Summary of Test Conditions

Test Conditions	Test Number			
	1	2	3	4
Simulant	113 g	42 g	113 g	113 g
Water	454 g	None	454 g	None
Detasheet	454 g	170 g	454 g	454 g

T-3 Vented Into	7.5 m ³ Flexible Tube	7.5 m ³ flexible Tube	375 m ³ VCS	375 m ³ VCS
DAAMS Tube Locations	In Flexible tube at 0.9, 1.8 and 2.7 m from T-3 exit	In Flexible Tube at 1.8, 2.7 and 3.7 m from T-3 exit	Two in VCS and two at air filtration unit exit	two in VCS and 2 at air filtration unit exit
Wipe Samples Taken From	One from floor of T-3 and one from exhaust manifold exit	One from floor of T-3 and one from exhaust manifold exit	One from floor of T-3 and one from exhaust manifold exit	One from floor of T-3 and one from exhaust manifold exit

Table 2. Concentrations of MS Found in Air and Wipe Samples

Test No.	Sample Number	Concentrations in Air (ug/m ³)	Concentrations From Wipe Samples (ug/cm ²)
1	1	1262	0.017
	2	307	0.004
	AVERAGE	784	0.011
2	1	171	0.004
	2	47	0.003
	3	138	-
	AVERAGE	119	0.004
3	1	125	0.034
	2	348	0.004
	AVERAGE	236	0.019
4	1	68	0.003
	2	131	0.034
	AVERAGE	100	0.019

Table 3. Total Micrograms of MS Recovered in Air and Wipe Samples

Test No.	DAAMS Air Samples	Surface Wipe Samples
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	Average (ug/m ³)	Final Plume Volume (m ³)	Total Found (ug)	Average (ug/cm ²)	Total Surface Area (cm ²)	Total Found (ug)
1	785	8.4	6,600	0.011	65,000	715
2	120	8.4	1,010	0.003	65,000	195
3	238	375	88,900	0.019	65,000	1235
4	100	375	37,500	0.019	65,000	1235

Table 4. Percentage of MS Destroyed In Each Test

Test No.	Initial Mass of MS (mg)	Total Mass MS Remaining After Detonation (mg)	% MS Destroyed By Detonation
1	113,500	7.3	99.99%
2	42,500	1.2	99.99%
3	113,500	90.1	99.92%
4	113,500	38.7	99.96%